AfriCultuReS Decision Support System Community Version (ADSS-CV).

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1. EXECUTIVE SUMMARY

One of the major societal challenges the world faces in the 21st Century is achieving global food security. A plethora of evidence shows that countries need significant advancements in their ability to manage limited freshwater resources, environmental change, as well as ensuring sustainable energy production. Eventually, all these factors must connect to ensure sustainable food supplies to meet the current and future demands. Although global efforts towards achieving food security have intensified, food security remains a challenge in Africa exacerbated by erratic rainfall patterns, increasing temperatures, as well as rising populations (generally characterised by poor households). In addition, agricultural production (both livestock and crop production) is threatened by increased frequency and intensity of climate-induced disasters such as floods and bushfires, proliferation of pests and diseases, and competing land-uses. In order to cope with increasing demand for food and achieve food security in the changing climatic conditions, agricultural production need to be intensified, either by increasing the size of productive land or by enhancing productivity. Agricultural intensification can be achieved through optimized farming, i.e. adopting state of the art farming methods and decision support tools that provide actionable information and services.

The use of satellite Earth observation (EO) data for assessment and monitoring of agricultural productivity is well established. These provide 'bird's eye' view of the landscape at frequent revisits thus are suitable for assessing the amount of food grown, predict gaps in seasonal or annual production, provide weather forecasts and commodity market information. The availability of free and open EO data at varying spatial and temporal resolutions offers several prospects for development of agricultural information products and innovative solutions that seamlessly integrate various EO data and in-situ data to provide actionable and reliable information that will aid precision agriculture, and informed decision and policy making.

Enhancing Food Security in AFRIcan AgriCULTUral Systems with the Support of REmote Sensing (AfriCultuReS, Grant Agreement No.774652), an on-going project, funded by the European Union Commission that is currently developing Decision Support System that integrates heterogeneous datasets such as EO data, weather and climate data and in-situ data, on current conditions and future scenarios about food production in Africa in a timely manner, from national, through regional, up to Pan-African scales. The project will deliver space based agricultural production services that are aligned with the African Space Policy and Strategy and AfriGEOSS, the African segment of the Group on Earth Observation (GEO) in the domain

of food security. Furthermore, AfriCultuReS is aligned with the United Nations Sustainable Development Goals 2 "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" and 13 "To take urgent action to combat climate change and its impact." The project also supports the articles 2 and 11 of the Paris Agreement on climate change related issues and human capital development.

The AfriCultuReS project will improve the innovation capacity of the members of food supply chains such as African farmers and food chain workers, public administration authorities, industry enablers and research organisations by providing them access to open agricultural production data, a set of validated satellite data and services through the innovative web and mobile AfriCultuReS platform. The project will also empower women smallholders with knowledge and tools relating to climate change and weather variability to improve their productivity.

The current CALL FOR PROPOSALS for GEO-Amazon Earth Observation Cloud Credits Programme is attractive to the African partners participating in the AfriCultuReS project AfriCultuReS recognises that boosting the impact of research and development (R&D) investments on food security must rely in the joint participation of European Union & African entities in the design, development and execution of research actions. Project consortium consist of approximately 50% of African institutions (i.e. 8 out of 17), bringing technical expertise, local knowledge and advice that will assure the accomplishment of the project. Participating countries, include South Africa, Niger, Kenya, Ghana, Rwanda and Mozambique, thus represent the diversity of African agricultural systems and the main food production regions in Africa. These countries/institutions lack infrastructural capacities to store, process and analyse Big data generated by multiple low to high resolution satellite missions such as ESA Copernicus Sentinels, NASA/USGS Landsat Data Continuity Mission (LDCM), MODIS, etc. The GEO-Amazon Earth Observation Cloud Credits Programme will allow AfriCultuReS African partners to rapidly access, manipulate, prototype and deploy processing chains and tools to derive EO-based informational products their swift distribution. In addition, this project will enable African partners to continue to offer operational AfriCultuReS services beyond the H2020 funding at no cost to the users.

2. PROJECT PLAN

2.1 OBJECTIVES

- To operationalize AfriCultuRes Decision Support System Community Version (ADSS-CV) for promoting sustainable agricultural systems and food security beyond H2020 funding by providing a Community version of the ADSS.

- To enhance the technical capacities of African partners in cloud computing for rapid product development and dissemination.

2.2 METHODOLOGY

2.2.1 SERVICE DEVELOPMENT, TESTNG AND DEPLOYMENT

The AfriCultuReS Decision Support System Community Version (ADSS-CV) will be comprised of four geospatial services, each responsible for delivering unique products related to Climate, Crop, Water and Livestock. The system will be developed following the Service Oriented Architecture (SOA) paradigm. Service-oriented architecture is a style of architecture based on services, where a service is a well-defined and self-contained functionality. In this architecture, different services communicate with each other to perform a certain activity. The services are loosely-coupled, meaning that a service does not need to know the technical details of another service that is interacting with. It only needs to know the input data to supply to the supported products, in order to retrieve the expected results. Basically, SOA consists of a service consumer and a service provider. The former requests data from a service, while the latter executes the request and returns the result. While communicating, the service provider and the consumer both adhere to a predefined protocol.

There are many benefits in using a service-oriented architecture, some of which are:

- Re-usability. The services can be reused in multiple applications.
- Reliability. Small independent services are easier to test and debug.
- Location Independence. The services can reside in different physical locations.
- Improved Scalability and Availability. Multiple instances of a single service can run on different servers at the same time.
- Platform Independence. Development of a complex product regardless of vendor or technology lock-in.

In the community version of the ADSS-CV platform, each service will either adhere to Open Geospatial Consortium's geospatial protocols, Web Map Service (WMS) and Web Coverage Service(WCS), or supply its output data to a central repository that has WMS and WCS capabilities, so that the data are provided to the portal client application. These standards are

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followed by numerous organizations and tools around the globe and help in improving the sharing of the world's geospatial data. Furthermore, the services will adhere to other standard protocols like FTP, SSH and HTTPS to interact with other services (internal or external) and provide intermediate results.

Test cases will be created in line with each of the above-mentioned services and tests run before deployment to ensure interoperability. Any failures that are identified in the test cases are fixed and test cases repeated to ensure the services are stable and working according to the requirements defined. The types of testing will be focused on unit testing, integration testing, user acceptance testing and performance testing. After successful testing, system deployment will follow.

2.2.2   SYSTEM AND PRODUCTS MAINTENANCE

The services will provide the data, a set of maps that will support the decision making in the field of food security in Africa. The data will be provided either using the WMS/WCS protocols and in the EPSG:4326 coordinate reference system or in a supported format that the THREDDS data server can host and serve, so that they are properly visualized in the portal. The services will also provide their data in other formats for use by other clients and/or for interactions between the services themselves. The ADSS-CV portfolio will include services such as climate, crop, water and livestock as listed in Table 1, section 3.

a.   Crop service

The Crop service provides information products for decision making on crop production, to this end the service entails multi-scale past assessment, seasonal and on-the-go crop mapping and crop condition monitoring as well as forecasts on expected yield for main crops. The service is written in the Python programming language and also makes use of the MATLAB programming platform. It relies on data from Copernicus Global Land Service, Sen2Agri, GIMMS Server and ESA Sentinel Hub for its operation. The crop service of ADSS-community version will constitute the following products; crop condition monitoring and assessment and crop phenology assessment. The products will be regularly updated depending on the most current releases by the providers and the type of the product. Crop Condition Assessment, Crop condition monitoring and Crop Phenology Assessment (upon data availability) and will be updated continuously.

- **Crop condition assessment**

The crop condition assessment products consist of information about the status of vegetation and crops. Crop condition is assessed directly through the use of vegetation indices such as

NDVI/EVI and biophysical parameters such as LAI or Vegetation Condition Index (VCI) which compares the current NDVI/EVI to the range of values observed in the same period in previous years. Multi-resolution products will be provided based on Copernicus Global Land Service and Global Inventory Monitoring and Modelling Studies (GIMMS) to provide course and medium resolution data, respectively. High resolution NDVI and LAI products will be retrieved from Sentinel-2 data at 10 and 20m spatial resolution using Sen2Agri system setup on the AWS cloud service to automatically download new data and compute required vegetation condition indicators in ADSS-CV project countries.

- **Crop Early warning**

For this service the following image products are generated and used:

Seasonal climate and weather forecasting alert: Providing information and advice on the past, present, and future state of the atmosphere is a central role of the Africultures meteorological and hydrological services, supported by global, and regional climate forecasting and prediction centers. This includes information on temperature, rainfall, wind, cloudiness, and other atmospheric variables and their influence on weather-and climate-sensitive activities and communities. The physical phenomena responsible for the weather and climate conditions are manifested at particular spatial and temporal scales which have important implications on observability, predictability, and service design.

Actual evapotranspiration alert: Evapotranspiration is, however, a more direct indicator of crop growth since it is a measure of the amount of water actually used by the crop. Its utility is illustrated by the following citation: "it has been demonstrated that for annual crops the difference between the potential and actual crop evapotranspiration will be proportional to the loss in biomass and, finally, the loss of economic yield" (Frere and Popov, 1986).

NDVI alert: NDVI is used as a proxy for crop status. The NDVI anomaly is a key variable within the Crop Monitor activities. This variable is used to monitor the vegetative state and health of the crops. A positive value indicates a more vigorous vegetative state of the crop compared to the averaged NDVI values. On the contrary, a negative value indicates a less vigorous state of the crop and it may suggest bad crop conditions or a slower growing rate of the crop due to environmental conditions.

- **Crop type layer**

The crop type layer (CTL) gives the most detailed picture of the cropland distinguishing the dominant crop types of a given region. Thus, the legend depends on the presence/absence of

particular crops in the region of interest recognized thanks to a machine learning approach. This concerns only mono-specific agricultural fields.

- **Crop Yield forecast**

The crop yield products will be developed by using Earth observation data and/or crop simulation models in order to give a precise, scientific sound and independent forecasts of crops' yield as early as possible during the crops' growing season by considering the effect of the weather and climate. Based on the user's needs this will be the approach used by the ADSS-CV's Crop Yield product. In this service, we will use the process-based crop modelling approach. Daily weather data required to drive a process-based crop model. Climate model output can also be used to run the model spatially. Crop yields will be simulated using the process-based model General Large Area Model for annual crops (GLAM) for the major crops identified in deliverable such as maize, sorghum, cassava, wheat, groundnut, sugarcane and potatoes.

Climate service

The climate service called AfriCultuReS Climdex Service will provide seasonal climate forecast, climatic conditions assessment, seasonal climate forecast, climate projections and seasonal climate early warning. The service will also obtain representative climate indices at a local scale and different time horizons (e.g. seasonal) building on state-of-the-art climate models (e.g. Copernicus seasonal forecasting system). This service will feed other AfriCultuReS services and impact models (e.g. crop modeling), and will allow to plan proper adaptation measures according with the climate conditions. The service is provided through the Santander User Data Gateway, a one-stop shop for climate data access built on a THREDDS server with an authentication layer and an R-based layer for climate data access and post processing. The AfriCultuReS Climdex Service will combine global predictions and projections with local observations (when available) to obtain a set of representative climate indices at a local scale to monitor climate conditions at different time-scales for early warnings about adverse events.

b. Livestock service

The Livestock service provides information products for decision making on livestock production. To this end, the service entails multi-scale past assessment, seasonal and on-the-go pasture and rangeland mapping and condition monitoring, as well as, assessment on the capacity of these productive environments to sustain livestock production. The service is written in the Python programming language and it relies on data from ESA Sentinel Hub for

its operation. Livestock service products will address information needs of the livestock production such as carrying capacity, grazing and browsing capacity, and rangeland condition monitoring products. These will be regularly updated depending on the most current releases by the service provider/s and users' needs.

- **Grazing and Rangeland Condition assessment and monitoring products**

The Grazing and Rangeland Condition assessment and monitoring products consist of provision of grassland and rangeland condition indicators using vegetation indices and biophysical parameters as well as their evolution through time. These products are useful for indicating the development and condition of vegetation throughout the season. The following products will be provided based on Sen2Agri system:

- Monthly aggregated NDVI at 10m spatial resolution.
- Monthly aggregated LAI at 10 m resolution. The LAI has a strong relationship with standing biomass and leaf properties such as Net Primary Productivity, thus it is critical for agro-ecological applications.
- Monthly aggregated Chlorophyll Content in Leaf (CAB) at 10 m spatial resolution.
- Monthly aggregated Fraction of vegetation cover (FCover) at 10 m spatial resolution. FCover quantifies the spatial extent of the area on the ground covered by green vegetation. It is independent of illumination direction and sensitive to the vegetation amount.
- Profiles of the indicators and biophysical parameters according to the specified time period, i.e. monthly, seasonal, yearly, etc. per village/magisterial district or user specified ROI.

The required data for the Grazing and Rangeland Condition assessment and monitoring products ADSS-CV for visualization and statistics.

- **Grazing and Rangeland mapping products**

Rangeland maps products will be provided based on existing datasets such at National/Global land cover datasets. The required data products will be acquired, processed within AWS platform and provided to the ADSS-CV for visualization and statistics.

c. **Water service**

This service will consist mainly of water bodies mapping and Soil Moisture Assessment updated regularly depending on the most current releases by the service providers and users' needs.

- **Water Bodies Mapping products**

Water Bodies (WB) mapping includes the detection of the areas covered by inland water. WB product is provided in various scales (incl. coarse, medium and high resolutions) and is thus developed by various service providers as described below. The mapping of WB over an entire year provides the maximum and the minimum extent of the water surface, as well as the seasonal dynamics. WB product is considered Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS). The assessment of extent and seasonal occurrence of WB can allow the monitoring and prediction of freshwater availability to populations and livestock, the provision of advice for water use and irrigation activities, and the support of agricultural knowledge and information systems.

- **Soil moisture assessment products**

The Soil Moisture Assessment product at coarse resolution is allows a comparison between the actual values of Soil Water Index(SWI) and SWI10 and the mean, max and min value computed for the same days of the year in the previous 10 years (2007 – present) provided by Copernicus Global Land Service. Therefore, Soil Moisture Assessment product enables the detection of any significant changes in soil moisture compared with previous years, which could have a serious impact on agricultural productivity. Near-Real Time SWI and SWI10 products, have the same characteristics of the original data source, i.e. Copernicus Global Land Service. The products have a 10km (0.1°) spatial resolution and for each pixel, the product provides eight SWI and SWI10 values.

2.2.3 VALIDATION OF SERVICE PRODUCTS

The services provided through ADSS-CV will constitute validated and un-validated products, open to be validated by the community. Validation will be carried out as per validation plan. The validation plan, developed in close collaboration with the end-users, will specify the pilot areas, the specific products to be validated, the time period of the validation, the person in charge for validation and the need for ancillary and independent data. Validation procedure will include using ground-based measurements collected by end-users and/or project partners, using Very High spatial resolution images, using data coming from other reliable sources and adopting an active crowdsourcing approach.

2.2.4 CAPACITY BUILDING AND USER APPRAISAL

Capacity building will be carried out through training workshops to ensure that the users are able to use the ADSS-CV and that the product are fit-for-purpose. The targeted users include, but not limited to, policy makers, researchers, farmers, funding institutions and insurance

companies. Surveys will be build-in into the system to collect feedback from the users for the continuous improvement of the system.

2.2.5 WORK DESCRIPTION

Project management & Coordination			
Participants	SANSA		
Start date	**M1**	**End date**	**M36**
The South African National Space Agency (SANSA) will be responsible for the coordination of project activities by other African partners and service providers, monitoring of cloud credits utilization, as well as the overall management of the project.			
Set-up, Testing and Deployment			
Participants	SANSA, CERGIS, LOCATE-IT, CGIS, GEOSAS, OSS, CRA, UEM, DRAXIS, SIA, AUTH, GMV		
Start date	**M7**	**End date**	**M18**
This activity constitutes the setting-up of the AfricultuReS Decision Support System Community version to the AWS Cloud Platform which will provide a subset of AfriCultuReS services. Its testing and deployment to ensure free agricultural monitoring services are offered beyond the funding from H2020.			
System and Products maintenance			
Participants	SANSA, CERGIS, LOCATE-IT, CGIS, GEOSAS, OSS, CRA, UEM, DRAXIS, SIA, AUTH, GMV		
Start date	**M10**	**End date**	**M36**
This activity will involve the setting up of the Sen2Agri system in the AWS cloud platform and continual development and update of the products. Each service provider will be able to serve latest product to the ADSS-CV.			
Quality Assurance			
Participants	SANSA, CERGIS, LOCATE-IT, CGIS, GEOSAS, OSS, CRA, UEM, DRAXIS, SIA, AUTH, GMV		
Start date	**M10**	**End date**	**M36**
This activity will constitute the continual quality assessment AfriCultuReS Decision Support System Community version infrastructure. Validation of the products will be designed and applied under AfriCultuReS project. However, other products will be distributed without validation, to stimulate community participation.			
Capacity building and Users Appraisals			
Participants	SANSA,CERGIS,LOCATE-IT,CGIS, GEOSAS,OSS,CRA,UEM		
Start date	M17	End date	M36
This activity constitutes the training activities with key stakeholders (beneficiaries/Users) of the ADSS-CV to acquire feedback for continuous improvement and customization of the system to the changing requirements of the users. Users will be made aware of the AWS cloud platform and services.			

2.3 TIMELINES

Activities	2019							2020												2021												2022				
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Project management & Coordination	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Migration, Testing and Deployment								■	■	■	■	■	■	■	■	■	■	■	■																	
System and Products maintenance											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Quality Assurance																				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Capacity building and Users Appraisals																				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

2.4 DELIVERABLES

AfriCultuReS project focuses upon seven services which are, accompanied with their IDs, Climate (AfriCRS-S1), Crop (AfriCRS-S2), Drought (AfriCRS-S3), Land (AfriCRS-S4), Livestock (AfriCRS-S5), Water (AfriCRS-S6) and Weather (AfriCRS-S7).

The current proposal for the "AfriCultuReS ADSS Community Version" focuses on four of these services which are Climate (AfriCRS-S1[CV]), Crop (AfriCRS-S2[CV]), Drought (AfriCRS-S3[CV]) and Livestock (AfriCRS-S5[CV]). The label [CV] in the services IDs stands for Community Version matching the taxonomy of services defined for AfriCultuReS. The tag aims at ensuring the traceability and maintenance of services.

The products are defined by the input data and information, the algorithms that process those data and the output type required by the end user. A building block is a partial input needed to achieve a product and, thereafter, a service. These services will be provided to all end users of the AfriCultuReS project. The products will be regularly updated depending on the most current releases by the providers and the type of the product. The services are listed in Table 1 below. Table 2 lists other AfriCultuReS services that will not be deployed in AWS, we list them here only to provide a complete overview of the project.

Table 1: List of AfriCultuReS ADSS Community Version services. The services will be implemented based on the availability of the cloud credits.

Service Name / ID	Service Description	Product Name
Climate **AfriCRS-S1** **AfriCRS-S1[CV]**	The Climate service provides information about mid-term climate variability and long-term climate change scenarios. The provided scientifically proven information and products aim at enhancing the user's knowledge and understanding about the impacts of climate on their field, allowing enhanced decision making.	Agro-Climatic Condition Assessment Seasonal Climate Forecast Climate Projections Seasonal Climate Early Warning
Crop **AfriCRS-S2** **AfriCRS-S2[CV]**	The Crop service provides information products for decision making on crop production, to this end the service entails multi-scale past assessment, seasonal and on-the-go crop mapping and crop condition monitoring as well as forecasts on expected yield for main crops.	Crop Condition Assessment Crop Type mapping Crop Yield forecast
Water **AfriCRS-S6** **AfrCRS-S6[CV]**	The Water service provides geospatial products for water quality and quantity assessment and monitoring. Other products are designed to deliver information on the amount of soil water available for crop growing as well as water productivity and crop water requirements	Water bodies mapping Soil Moisture Assessment
Livestock **AfriCRS-S5** **AfriCRS-S5[CV]**	The Livestock service provides information products for decision making on livestock production. To this end, the service entails multi-scale past assessment, seasonal and on-the-go pasture and rangeland mapping and condition monitoring as well as assessment on the capacity of these productive environments to sustain livestock production.	Grazing and Rangeland Condition Monitoring Grazing and Rangeland Mapping

Table 2: List of other AfriCultuReS services (not to be deployed in the ADSS Community Version), products are omitted

Service Name / ID	Service Description
Land **AfriCRS-S4**	The Land service provides facts on land cover current situation and land cover changes as well as abiotic factors that affect, or can affect, food production
Drought **AfriCRS-S3**	The drought service provides information products on drought monitoring and early warning.
Drought **AfriCRS-S7**	The Weather service provides ten-day to near real time weather forecast. Forecast and weather records will serve to deliver early warnings on weather extremes and to predict (candidate product) the outbreak of weather driven crop pests and diseases.

2.5 CLOUD CREDITS
2.5.1 ADSS COMMUNITY VERSION DATA REQUIREMENTS

Country	MODIS	Landsat Scenes	Sentinel Scenes	Total estimated data volume
ETHIOPIA (ET)	4 (0.33 GB)	65(56.88 GB)	161(78.61 GB)	135.82 GB
GHANA (GH)	4 (0.33 GB)	20 (17.50 GB)	43(20.99 GB)	38.82 GB
KENYA (KN)	4 (0.33 GB)	33(28.88 GB)	89(43.46 GB)	72.67 GB
MOZAMBIQUE (MZ)	5 (0.41 GB)	55(48.13 GB)	126(48.13 GB)	96.67 GB
NIGER (NE)	4 (0.33 GB)	68(59.50 GB)	168(59.50 GB)	119.33 GB
RWANDA (RW)	2 (0.16 GB)	4(3.50 GB)	9 (4.40 GB)	8.06 GB
SOUTH AFRICA (ZA)	5 (0.41 GB)	82(71.75 GB)	187(91.31 GB)	163.47 GB
TUNISIA (TN)	1 (0.08 GB)	23(20.13 GB)	31(15.14 GB)	35.35 GB
African Continent	40 (3.3GB)	-	-	40 (3.3GB)

2.5.2 ADSS CLOUD CREDITS

⊟ Amazon EC2 Service (US East (N. Virginia))			$ 2459.99
Compute:		$ 2192.49	
EBS Volumes:		$ 247.50	
EBS Snapshots:		$ 20.00	
⊟ AWS Support (Business)			$ 246.00
Support for all AWS services:		$ 246.00	
Free Tier Discount:			$ -0.05
Total Monthly Payment:			$ 2705.94

Total cost for 36 months **$ 97413.84**

3. PARTICIPATING ORGANISATIONS

Organisation	Role	Address	Contact Person
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Centre for Geographic Information Systems and Remote Sensing (CGSI), University of Rwanda - Rwanda.	Participant	Centre for GIS and Remote Sensing (CGIS) College of Science and Technology (CST University of Rwanda KN 73ST, Kigali PO Box 3900, Kigali - Rwanda	Dr Gaspard Rwanyiziri Director of CGIS g.rwanyiziri@ur.ac.rw
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